Signatures of broken symmetries in a quark gluon plasma [1]

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One of the most promising signatures for the formation of a quark gluon plasma (QGP) in a heavy ion collision has been that of the electromagnetic probes, *i.e.* the spectrum of lepton pairs and real photons emanating from a given collision. These particles once produced interact only electromagnetically with the plasma. As a result they escape the plasma with almost no further rescattering and convey information from all time sectors of the collision. We explore the observational consequences of certain broken symmetries in a thermalised QGP on the spectrum of dileptons radiating from it. The primary motivation for measuring such a spectrum is the hope that the formation of a QGP in the history of a collision will produce a qualitative or quantitive difference in the observed rates.

The channel under investigation is two gluon fusion leading to e^+e^-. This is a pure medium effect: it is non-vanishing only in plasmas with explicit broken charge conjugation invariance. It is now well established that the central region at RHIC is not just heated vacuum, but actually displays a finite baryon density. It may be argued that any baryon number asymmetry prevalent in the QGP must have been introduced by valence u and d quarks. In such a scenario a finite baryon density may lead to a finite charge density, the presence of which breaks Furry's theorem. Diagramatically this means that the sum of the diagrams of Fig. (1) is finite. The vacuum counterpart of this process is constrained by Furry's theorem and is identically zero

The rates are also sensitive to constraints imposed by rotational invariance. The vacuum analogue of the two-gluon-photon process represents an instance of two identical mass-
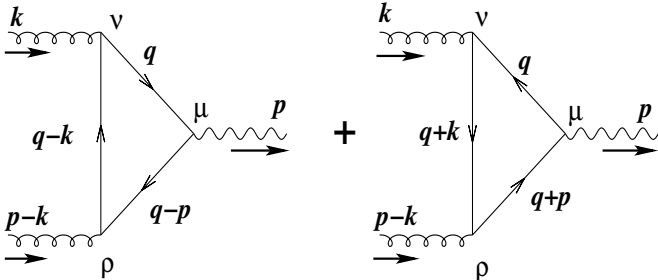
less vectors fusing to form a massive spin one object. Such a process is not allowed in the vacuum due to Yang's theorem. The introduction of the medium formally involves the introduction of a new four vector **n** into the problem. In the case of dileptons produced back-to-back in the rest frame of the medium ($\mathbf{n} = (1, 0, 0, 0)$). This four vector cannot in any way introduce rotational non-invariance in the problem. However, if the two gluons are not exactly back-to-back or equivalently the medium has a net three momentum, then rotational invariance is explicitly broken.
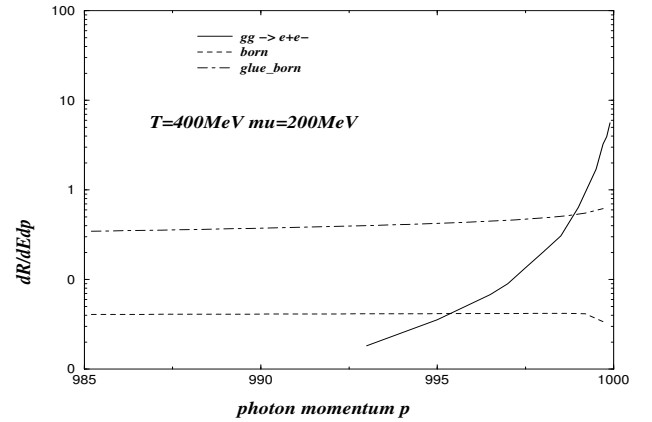
FIG. 2: Differential rate for the production of dileptons at high mometa. See text for details.

Yang's theorem is understood in the medium via the incomplete destructive interference between various multiple scattering diagrams obtained by the spectator interpretation. The virtual photon has a net three momentum in the rest frame of the bath. The magnitude of symmetry breaking rises with the magnitude of the three momentum. The differential rates are presented in Fig. (2). The dashed line is the rate from the Born term, while the solid line is the rate from gluon gluon fusion. The rate from gluon gluon fusion greatly dominates over the Born term at high momenta or low invariant mass. The energy of the dilepton is 1 GeV in this case. ' We also plot the Born term with massless quarks and with the Fermi-Dirac distribution functions replaced with Bose-Einstien distribution functions. This gives us the dot-dashed line We thus demonstrate that in some regions of parameter space the rate from this process dominates over the Born term.

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FIG. 1: The two gluon photon effective vertex as the sum of two diagrams with quark number running in opposite directions.